

# PATENT SPECIFICATION

DRAWINGS ATTACHED

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## Improvements in or relating to discharge lamp envelopes.

### COMPLETE SPECIFICATION

We, GENERAL ELECTRIC COMPANY, a Corporation organized and existing under the laws of the State of New York, residing at 1 River Road, Schenectady 5, New York, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed to be particularly described in and by the following statement:

This invention relates to resonance radiation discharge lamps, for instance fluorescent lamps, which comprise an ionizable medium and an elongated hollow thin-walled envelope of vitreous material generally having a greater ratio of circumference-to-area of cross-section than a lamp with circular cross-section and equal circumference. The main U.K. specification No. 821,321, to which the present application is an addition, relates to discharge lamps of the kind above mentioned. According to the main patent, the lamp envelope is so shaped that it has, apart from circular tubular sections, one or more sections each having an outwardly open deep transversely re-entrant groove extending longitudinally of the envelope so as to provide a kidney-shaped cross-section in which the wall portion forming the groove is spaced substantially uniformly from the arcuate wall portion opposite thereto, and is joined to said arcuate wall portion by curved wall portions having a radius of curvature approximately one-half the distance between the groove forming wall portion and the arcuate wall portion opposite thereto, and in which the length of the periphery of the envelope cross section measured along the re-entrant groove wall portion is of the order of one-half that of the opposite arcuate wall portion.

Such a configuration provides a high ratio of perimeter to area of the cross section along with relatively high implosion resistance.

Resonance radiation lamps of this cross section, for instance a fluorescent lamp utilizing the resonance radiation of mercury vapour at 2537A° to excite a phosphor coated internally on the walls of the envelope to produce visible light, achieve higher loading and lumen output per unit axial length at a given efficiency than heretofore possible. These lamps also have other desirable characteristics among which may be mentioned those of providing a preferential light output in the sector of the cross section which includes the groove and of improved vapor pressure regulation.

Re-entrant lamps with the groove extending continuously and uninterruptedly along one side of the envelope are most desirable from the point of view of electrical characteristics and performance. However their strength and implosion resistance are not as high as those of other re-entrant lamp configurations such as, for instance, those wherein the lamp is divided into grooved panels by means of upstanding ribs of generally circular cross section. To assure adequate strength for a reasonable margin of safety in continuous groove lamps in the larger sizes of tubes, for instance tubes of nominal diameter of 5.4 cm, it has been necessary to resort to relatively thick-walled tubing. Understandably, such tubing is more costly, more difficult to manufacture and process into lamps, and results in a heavier lamp whose greater weight is of itself a disadvantage.

Therefore, an elongated vitreous discharge lamp, as claimed in the main specification No. 821,321, which has a generally tubular form with a transversely re-entrant groove extending longitudinally of the envelope to form a discharge space with kidney-shaped cross section, is improved according to the present invention in such a manner that regions of maximum stress at the bottom of the concave groove forming wall portion and

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at the convexly curved wall portions on either side of the groove are of increased wall thickness relative to the remainder of the envelope wall.

- 5 By preferentially increasing the wall thickness of these regions, for instance by making the walls approximately twice as thick as over the remainder of the envelope cross section, the maximum stress due to atmospheric pressure acting on the envelope is substantially reduced, resulting in a lamp of improved implosion resistance without commensurate increase in weight by relation to that entailed by a uniform increase in wall thickness.

For a more detailed description of the invention, attention is now directed to the following description with reference to the accompanying drawings, wherein

- 20 Fig. 1 is a pictorial view of a discharge lamp embodying the invention with a transversely re-entrant longitudinal groove extending uninterruptedly along its underside, portions of the envelope wall being broken out to shorten the figure and to reveal the internal construction.

Figs. 2 is a cross sectional view of the lamp of Fig. 1.

- 30 Fig. 3 is a cross sectional view of circular sectioned tubing from which the envelope of Fig. 1 may be made by suitable reforming.

Referring to Fig. 1, there is shown a fluorescent lamp 1 of the low-pressure positive column type embodying the invention.

- 35 The lamp comprises an elongated vitreous envelope 2 having circular or round tube ends 3,3 which are annularly reduced or shouldered at their extremities for securing thereto bases 4,4. The bases may be of the double-recessed contact type comprising a dished metal shell 5 to which is secured a disc 6 of an insulating plastic provided with a raised elongated embossment 7. The outward projections of the lead wires 8, 9 extend through a central passage in the disc into the recessed outer face of the embossment to serve as contact terminals.

- As shown at the end of the lamp having the cutaway portion, an electrode mount or stem flare 11 is sealed peripherally into each circular tube end and includes a press 12 through which are sealed the current inlead wires 8,9. The inward projections of the lead wires support the filamentary cathode 55 13 which may consist of a coiled-coil of tungsten wire provided with an overwind and coated with an activated mixture of alkaline-earth oxides, such as the usual mixture comprising barium and strontium oxide. One of the stem flares is provided with an exhaust tube which is sealed or tipped off in the usual fashion.

- The lamp contains an ionizable atmosphere including an inert starting gas at a low pressure, for instance argon at a pres-

sure of a few millimeters of mercury, and mercury vapor. The droplets of mercury indicated at 14 exceed in amount the quantity vaporized during the operation of the lamp wherein the mercury vapor exerts a partial pressure in the range of 1 to 20 microns for optimum generation of mercury resonance radiation at  $2537\text{\AA}$ . A phosphor coating indicated at 15 of the inside of the envelope converts the  $2537\text{\AA}$  radiation into visible light.

Along the underside of vitreous envelope 2 is provided a transversely re-entrant portion or groove 16 which extends longitudinally the entire length of the envelope between the round ends 3,3 so that a biducy-shaped cross section results. The cross section of the envelope may be visualized as a flattened tube which has been rolled up transversely into an inverted U-shape. More exactly, the cross section of the discharge space may be described as a sector of an annulus defined by generally concentric walls 17 and 18 and bounded by rounded convex edge walls 19,19'. Convex outer wall 17 has the minimum curvature, its radius being substantially that of the original round tube from which the present grooved tube was formed. Concave inner wall 18 has a greater curvature than outer wall 17, its radius of curvature being approximately one-third that of outer wall 17. Convex edge walls 19, 19' are provided with a slightly greater inside curvature than concave inner wall 18. This is done because whereas it is desirable to have the wall-to-wall spacing substantially constant, it is essential to avoid a constriction at the medial line of the cross section because of the tendency of the discharge to occupy the space to one side or the other of the constriction. Since moulding of glass cannot in any event be performed with perfect accuracy, a practical solution resides in making the inside radius of curvature of the convex edge walls somewhat less than that of concave inner wall 18, or somewhat less than one-half the maximum wall-to-wall spacing of the concentric outer and inner walls 17, 18. Preferably the groove is provided with more or less straight slanting wall sections 21,21' interposed between the curvatures of the top of the groove and of the edge walls. The side walls of the groove are thus outwardly divergent, that is, slanting downwardly and outwardly.

Typical dimensions of re-entrant groove lamps of nominal outer diameter of 5.4 cm and a length from 1.22 to 2.45 meters in which the invention may be embodied are as follows, reference being made to Fig. 2. The radius of curvature T of outer wall 17 is approximately 2.7 cm measured to the outer surface. The radius of curvature A of wall 18 at the top of inner curve of the groove

is approximately 7.9 mm measured to the outer surface of the glass. The radius of curvature B of the edge walls 19, 19' is approximately 8.3 mm measured again to the outer surface of the glass. The center of the radii of curvature of the edge walls is located a distance C equal to 2.4 mm below the center of the radius of curvature of the concave inner wall 18. The slanting side walls of the groove slope outwardly at an angle to the medial plane through the groove, which angle is in excess of 15°, for instance approximately 27°. Regarding radii A and B of the groove and of the edge walls, the thickness of the glass must be added to the former and subtracted from the latter to provide the radii of curvature of the inside surface which determines the cross section of the discharge space.

The gaseous filling of low-pressure discharge lamps, such as fluorescent lamps, is at such a low pressure relative to the atmosphere that, for all practical purposes, the envelopes may be considered evacuated.

Resistance of the envelopes to implosion or inward collapse by reason of external atmospheric pressure is thus highly significant. In envelopes of circular cross section, the radial pressure of the atmosphere on the walls is converted into substantially uniform circumferential compressive stress in the glass walls. In re-entrant groove lamps, on the other hand, the stress is not uniform. Pressure tests of large numbers of re-entrant groove lamps have demonstrated that the maximum stresses are highly localized in three rather narrow zones, these being the inner curve or concave end wall of the groove as seen in cross section, and the edge walls of the envelope on either side of the groove, particularly the outer curve thereof. This is demonstrated experimentally by observing the pattern of fracture of the envelope when it is submitted to excessive external pressure, for instance in a hydraulic pressure chamber. It can also be confirmed by weakening the glass as by scratching it in the zones of maximum stress; scratches in the glass in those zones substantially lessen the implosion resistance of the envelope whereas in other areas they are of less or substantially no consequence.

Mathematical analysis of the stresses in envelopes of uniform wall thickness as indicated in dotted lines at 2' in Fig. 2, indicate that point *a* in the center of convex outer wall 17 is subject to minimum bending moment; points *b*, *b'* in the outer curves of edge walls 19, 19', and point *c* in the center of concave inner wall 18 of the groove are points of maximum bending moment, the greater maximum being at *c*. The stress in the walls varies with the bending moment, however the bending moment is of opposite sign at points *a* and *c* compared with points

*b, b'*; at points *b, b'*, the outer wall surface is in tension and the inner wall surface is in compression; at points *a* and *c*, the outer wall surface is in compression and the inner wall surface is in tension.

Computations on the basis of a uniform wall thickness of 1.27 mm and on the assumption of a stress which varies linearly across the wall thickness, provide the following estimates of the maximum stress  $\bar{S}$  at points *a, b* (and *b'*), and *c* under atmospheric pressure, that is under a pressure of approximately 1 normal atmosphere.

$$\bar{S}_a = 35 \text{ kg per cm}^2$$

$$\bar{S}_b = 560 \text{ kg per cm}^2$$

$$\bar{S}_c = 840 \text{ kg per cm}^2$$

As the wall thickness is increased, the stresses vary approximately inversely as the square of the thickness. For instance, increasing the wall thickness from 1.27 mm to 1.52 mm or in the ratio of 5:6, i.e. by 20%, will reduce the maximum stresses given above in a ratio of approximately (6)²:(5)², that is to values about 70 per cent of those given in the above tabulation.

In accordance with the invention, the wall thickness of the envelope is differentially increased in selected areas corresponding to the regions of localized stresses and particularly at the inner curve or concave end wall of the groove in the region of point *c*, and at the edge walls of the envelope, particularly on the outer curves thereof in the regions of point *b, b'*. For instance the wall thickness may be 1 to 1.5 mm throughout the major part of the cross section and 2 to 3 mm at the points *b, b'* and *c* with a gradual taper back to the 1 to 1.5 mm thickness on either sides of those points. By so doing, the maximum stress in the envelope walls is substantially reduced, for instance to approximately half the values given in the foregoing tabulation, without commensurate increase in the overall weight of the envelope. For instance the weight of the envelope will increase by as little as 30 per cent of an increase of weight if the wall thickness throughout the entire cross section were uniformly increased to the extent necessary to achieve the same implosion resistance.

The foregoing tabulation would indicate that on the basis of the maximum stress concentrations, point *c* in the center of the inner curve of the groove has a stress concentration at 840 kg per square centimeter which is approximately 50 per cent higher than at points *b, b'* on the outer curves of the edge walls at 560 kg per square cm. It would appear therefrom that the walls should be thickened more at point *c* than at points *b* and *b'*; however such may not necessarily be the case in practice. Indications are that failure of a lamp on an implosion test generally occurs as a result of an imperfec-

tion or scratch in a region of high stress concentration. Furthermore, a flaw or scratch is of much greater significance in a region of tensile stress than in a region of compressive stress, glass being much weaker in tension than in compression. However, at the region *c*, it is the inside surface of the wall which is in tension and that surface of course is not subject to handling and scratching. At the points *b, b'* on the other hand, it is the outside surface which is in tension and here the possibility of scratching is very prevalent. Accordingly, as a practical matter, it may be just as important or even more important to increase the wall thickness and thereby reduce the maximum stress concentration about the points *b, b'* on the outer curves of the edge walls than at the point *c* on the inner curve of the groove.

By reason of the strains set up in the glass walls due to non-uniform heating of the envelope during operation of the lamp, there are practical limits to the extent to which the walls may be differentially thickened in order to increase strength and implosion resistance. In general, the upper limit to the ratio of maximum to minimum wall thickness is of the order of 3 to 1 for the usual sizes of tubular lamp envelopes from 2.5 to 5.5 cm in diameter, and a ratio of approximately 2 to 1 is preferred for most applications.

A re-entrant groove lamp with the walls preferentially thickened in the regions of maximum stress concentration may be made by drawing the grooved and differentially thickened tubing directly or by reforming a differentially thickened tube of circular section. The wall thickness of the round tubing 22 illustrated in Fig. 3, is preferentially thickened in the regions *b, b'* and *c*, corresponding to the regions *b, b'* and *c* in Fig. 2 wherein the re-entrant groove envelope cross section is to be thicker. The reforming may be done by heating the round envelope to its softening point and then clamping a suitable mold about it to reform the envelope to the desired configuration. The reforming of the round envelope may also be done by a process wherein the tube is heated in a selected zone corresponding to the region of the groove to its softening temperature, for instance to approximately 540°C in the case of a lime glass envelope; a suitable plunger with a projecting ridge or protuberance corresponding to the groove is then pressed down on the envelope, the protuberance contacting the surface of the envelope in the zone where the glass is heated above its softening temperature. This

causes the surface of the envelope to fold inward in that zone, thereby forming the re-entrant groove. Preferably the protuberance achieves contact with the vitreous envelope in the inner curve 18 of the groove but not along the convex edge walls 19, 19', the glass being allowed to form freely at these edge walls.

While a specific embodiment of the invention has been illustrated and described in detail, it will, of course, be understood that various modifications may be made without departing from the invention.

#### WHAT WE CLAIM IS:

1. An elongated vitreous discharge lamp as claimed in any one of the claims of U.K. Specification No. 821,321, having an envelope which has a generally tubular form with a transversely re-entrant groove extending longitudinally of the envelope to form a discharge space with kidney-shaped cross section, characterised in that regions of maximum stress at the bottom of the concave groove forming wall portion and at the convexly curved wall portions on either side of the groove are of increased wall thickness relative to the remainder of the envelope wall.

2. An elongated vitreous discharge lamp according to claim 1, wherein the wall thickness of the envelope wall cross-section from a point at the center of the concave inner curve of the groove and a point in the outer curve of the convex edge of the walls on either side of the groove is tapered in thickness to the minimum thickness of the remainder of the wall.

3. An elongated vitreous discharge lamp according to claims 1 or 2, wherein the ratio of maximum to minimum wall thickness throughout the cross section of the envelope is not in excess of approximately 3 to 1 and is preferably approximately 2 to 1.

4. An elongated vitreous discharge lamp according to any one of the preceding claims, wherein the side walls of the envelope groove are more or less straight wall portions inclined at an angle of more than 15° to the medial plane through the groove.

5. An elongated vitreous discharge lamp of generally tubular form substantially as described with reference to and as illustrated in the accompanying drawings.

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